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No. 790.

# THE NEW WATER-WORKS OF HAVANA, CUBA.

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PRESENTED SEPTEMBER 16TH, 1896.

WITH DISCUSSION.

The first attempt to supply the city of Havana with water was made in 1835, by the construction of the "Aqueducto Fernando Sétimo," which introduced the water of the Almendares River for public use. This supply was very inadequate. The water was diverted at a point about 4½ miles from the city, and, after passing through a rude and defective filter, was brought into the city in an 18-in. cast-iron pipe. This supply only amounted to about 1 333 000 galls. per 24 hours, and was liable to become very turbid from surface wash, the clarifying effect of the rude filtration being of slight account.

In order to obtain a better and more abundant supply, it was decided to collect in a suitable basin, a large number of springs which were found in the neighborhood of Vento, situated upon the River Almendares, about 10 miles from Havana. This idea seems to have originated with General Concha, and its execution was entrusted to

General Francisco Albear, who at the time was President of the Board of Public Works of Cuba, and to whose genius and ability the credit of getting the project into practical shape is wholly due.

This new project was inaugurated November 28th, 1858, and in February, 1859, General Albear took charge of the work. The two following years were spent in surveys, examinations, collecting materials and other necessary preliminaries.

The springs, some 400 in number, giving a calculated yield of about 40 000 000 galls. per 24 hours, were collected in a large masonry-lined basin, with suitable overflows and sluices. These springs are situated near the river, on the farther bank from the city, and a high retaining wall forming one side of the basin prevents the entrance of the water of the river when it is swelled by freshets. A tunnel was constructed under the river, in which two lines of cast-iron pipe 1 m. in diameter were laid. These pipes connect with a masonry aqueduct about 6 miles long leading to the distributing reservoir at Palatino. This aqueduct is oval in section, about 8 ft. high and 6.5 ft. in maximum width, with a total sectional area of 41¼ sq. ft., and an area below the spring line of the arch of 24½ sq. ft. The slope is $\frac{1}{5000}$, and the estimated velocity, when running to the level of the spring line, 2.43 ft. per second, delivering 59 cu. ft. per second, or about 38 000 000 galls. per 24 hours.

The first stone in the main wall of the collecting basin was laid June 26th, 1861. The first stone of the tunnel was laid in May, 1865. The water first ran through the pipes laid in the tunnel March 1st, 1872. The circumstances which brought about this slow progress are too numerous, complicated and uncertain to be entered into here. As it would evidently have been unwise to delay the delivery of at least a part of the water until the completion of the work, it was determined to connect that portion of the aqueduct already built with the old distribution. Accordingly, in June, 1872, the aqueduct was connected with the filter beds, already mentioned, and a partial supply of water, of improved quality, was thus obtained.

The total actual cost of the works executed up to the death of General Albear in October, 1887, according to his official statements, was under $3 500 000. These works included the receiving basin, tunnel and aqueduct. Of the thirty years which intervened between the commencement of the work in 1859 and its resumption in 1889,

about to be described, there were only ten in which actual work was done, owing to want of funds and political disturbances.

Meanwhile the project of the new water supply had attracted the attention of American capitalists. The late Daniel Runkle, then President of the Warren Foundry and Machine Co., studied the project carefully, aided by the late J. C. Campbell, M. Am. Soc. C. E., then Chief Engineer of the Croton Aqueduct, who visited Cuba for the purpose, with the result that, in November, 1889, a contract for the completion of the works, comprising the building of the Palatino distributing reservoir and piping the city, was awarded to Messrs. Runkle, Smith & Co., of New York, who were represented in Havana by Mr. Richard Narganes, the president of the advisory board in Havana being the Marquis of Pinar del Rio.

The new works were inaugurated January 31st, 1890. The author, after a preliminary visit to Havana to report upon the project, was engaged by Messrs. Runkle, Smith & Co. as their engineer for the execution of this contract. He reached Havana in February, 1890, and preparations were at once commenced for work.

The contract for the entire work, including furnishing and laying the pipe, and building the reservoir, was taken at the engineer's estimate. The system of estimating public works in Cuba is somewhat peculiar. The plans having been prepared, an estimate is made of the exact quantities of each class of work required, down to the minutest detail. The plans, quantities and estimates, accompanied with a report, are then forwarded to the home government, in Spain, and if approved are forwarded back and can be acted upon. After such approval, it is extremely difficult to have any changes made, anything radical involving first acceptation by the proper authorities in Cuba, and then submission to the home authorities, and a royal order for the change. A feature which is frequently embarrassing is that the quantities and cost of each class of work must stand by themselves. If, in the execution of the work, the quantity, and consequently cost, of one class should fall short of that estimated, the surplus would not be available for making up the deficit in any other class which might overrun the estimate. Hence, the anomalous circumstance might occur, of being obliged to ask for a new appropriation for extra work, while there was still an unexpended and unexpendable balance on hand. The full set of documents of such a project comprise *planos*, *mediciones*, *presupu-*

*esto* and *memoria.* The *planos* are the general drawings, illustrating the entire project, but only in a general way; the *mediciones*, or measurements and quantities, must be given, if expressible in cubic measurements, by the number of similar pieces of work, with their common length, breadth and thickness, which factors, multiplied together, give the total cubication. It will be readily perceived how inconvenient this rule is when dealing with pieces of masonry of irregular shape. In such cases the actual cubature must be first calculated, and then the amount divided up in such a way as to be expressible under the three dimensions of length, breadth and thickness.

There is another singular rule regarding the execution of public works in Cuba, which it is believed holds good in Spain also, which is, that implicit conformity to all plans and instructions given by the chief engineer does not relieve the contractor from the responsibility of failure, should it ensue, unless before commencing the work he files a written protest. In other words, his acceptance of a contract after examination of the plans and documents is held to be an approval of the design, which then virtually becomes his own, and for the success of which he, and not the engineer, is responsible. The want of reasonable foundation for this extraordinary regulation made it impossible for the author to believe in its existence until it was affirmed to him by unimpeachable authority.

The work to be done under the contract contemplated, besides the furnishing and laying of the pipe, the building of the distributing reservoir already mentioned. This reservoir is about 4 miles from the city. It is almost wholly in excavation, and consists of two compartments, or tanks, each containing about 8 000 000 galls. The bottom is covered with a concrete floor, and the sides are formed of rubble masonry retaining walls. From outside to outside of foundations of both tanks the area covered is 245 x 500 ft., or about 2.8 acres. The elevation of the bottom above city datum (which is understood to be mean low water) is 95.57 ft. The elevation of the lip of the overflows is 114.83 ft. The height of the retaining walls, from the level of the concrete floor to the top of the wall, is 20.5 ft. The top thickness of the wall is 2.79 ft.; its bottom thickness, not counting a small off-set, 6.73 ft. The face has a batter of 1 in 10, and the back is built in offsets. The area of cross-section is 97.20 sq. ft.

Water is admitted to this reservoir from the aqueduct through an influent gate chamber. It may be admitted into either side of the reservoir, or both sides at once; or it may be shut off from either or both, and run through a masonry culvert in the center wall directly into the effluent gate chamber. The water may be also entirely shut off from the reservoir and gate chamber and turned into a waste culvert passing around the reservoir. Each side of the reservoir has an overflow discharging into the culvert, and there is another overflow in the aqueduct just before entering into the influent gate chamber. All the above operations are effected by sluice gates.

The effluent gate chamber contains a number of openings controlled by sluice gates, of which there are twelve in all used at the reservoir. From these openings the water enters a collecting pipe 42 ins. in diameter, running parallel to the side of the reservoir. Out of this pipe run the various other pipes destined for the distribution of the water to different parts of the city. These pipes, as well as the collector, are governed by valves. This part of the work will be referred to again. For the present it will suffice to say that the working of the system was perfectly satisfactory, although compared with the means usually employed in the United States to accomplish the same purpose, it appears unnecessarily complicated.

The original project contemplated a covered reservoir, which would seem to be especially proper in a tropical climate. The general drawings showed a series of granite columns, spaced 20 ft. apart from center to center, supporting a roof of concrete in the shape of groined elliptical arches, the concrete at the crown of the arches being about 1 ft. thick. The granite pillars were to consist, above the base block, of three stones each, respectively 7.38 ft. high by 2.63 ft. square, 6.56 ft. high by 2.30 ft. square, and 5.58 ft. high by 1.97 ft. square. These separate blocks were to be superposed, one upon the other, joined only by a bed of mortar, and were to be surmounted by a granite capital, forming a skewback whence the groined arches were to spring.

The great difficulties attending the execution of this design were apparent at first sight, and an endeavor was at once made to substitute a simpler and more common method for covering the reservoir. Several plans were submitted, with estimates showing their greater economy, safety, ease and rapidity of execution, the merit of which, as compared with the original design, was recognized by the highest

authorities, both in Havana and Madrid, but they met with great opposition from the city officials, and, finally, after prolonged discussions, the question was left an open one as to whether there should be any cover built at all. There the question remains to this day.

The amount of money called for by the estimates was furnished by the Spanish Bank of the Island of Cuba, and was paid to the contractors in monthly installments as the work progressed, the estimates being signed by the engineer-director of the works, and the engineer-inspector appointed by the bank. The director of the works was Major Joaquin Ruiz, and the inspector, Major Ricardo Seco. Colonel Lino Sanchez acted as consulting engineer for Major Ruiz. All these gentlemen belonged to the Royal Spanish Engineer Corps.

The excavation for the reservoir was immediately commenced under the charge of Mr. Hector Simonetti. Disappointments occurred at the start from not getting the amount of Decauville plant of track and cars which had been ordered, but work was nevertheless started with all the means at command—plows, ox and mule carts, wheelbarrows, etc. The mule teams were soon discarded; each cart only took about 0.5 cu. yds., and, as it was made fast to the shafts, the harness had to be unbuckled to allow the shafts to be raised in order to dump. The oxen did somewhat better; the carts took 0.75 cu. yds. and could be more easily dumped, but the oxen were very slow and required much water and two hours' rest towards the middle of the day. Late in March, 1890, some wheel and drag scrapers were received from New York which the men could not at first use, and the wheel scrapers were never used satisfactorily. After the use of the drag scrapers had been acquired, they proved very efficient. By the last of April about 50 000 cu. yds. of excavation had been taken out from the reservoir site and the first section of the pipe line, which also required heavy cutting. Early in May some American dump cars and track were received, and a stationary engine erected, to haul the cars out of the reservoir. During the whole of the work, this engine was the main dependence in getting out the material.

Early in May, 1890, the author returned to the United States to collect plant, engage a force of American masons, and prepare for an active prosecution of the work as soon as the rainy season should be past. Mr. A. G. Midford was engaged as general superintendent of

FIG. 1.

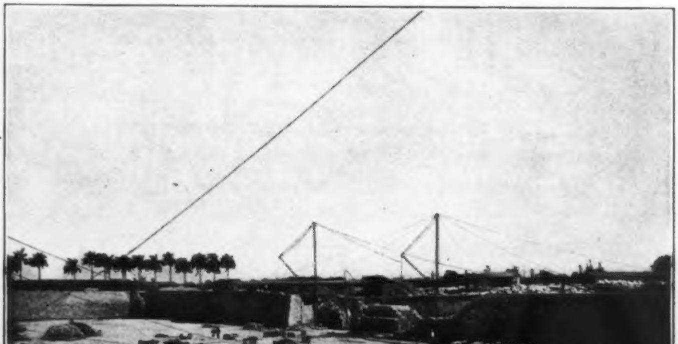

FIG. 2.

the work at Palatino, and a gang of masons was made up by him in New York. Four pipe calkers were also engaged, who soon trained a gang of Cuban calkers to do good work. Four pipe derricks and four boom derricks, two with 50-ft. booms and two with 40-ft. booms, two double spring carts and one large sling truck for the transportation of pipe were shipped from New York. The sling truck was intended for handling 42-in. pipe. It may be here stated that in practice the spring carts were found handier even for the large pipe, and the truck was seldom used for this purpose. It was found very convenient, however, on many occasions when heavy objects, machinery, etc., had to be moved. Lead ladles, furnaces, and several double and single drum hoisting engines were procured. A stone crusher and a concrete mixer were also shipped, as well as considerable miscellaneous plant, including a testing machine for the pipes, and a cement testing machine.

The author reached Havana with his assistants early in October, 1890. Work had been continued in excavating for the reservoir and pipe line under Mr. Simonetti, assisted by Mr. Manuel A. Pelaez, a Cuban engineer, until July 31st, when the rains made it expedient to suspend the work.

Many delays occurred at the start incident to the commencing of such a large and complicated undertaking in a foreign country and under foreign direction, so that, although the masons were immediately set to work preparing stone, and doing whatever building they could be put at along the line, it was not until November that laying concrete and masonry commenced at the Palatino reservoir. Fig. 1, Plate VII, is a view of the work, looking west, as it appeared on January 19th, 1891.

The concrete bottom is 1 ft. thick and was laid in two courses of about 6 ins. each. This was covered, later, with a finishing course laid with a slight slope toward the discharge pipes which served to empty the reservoirs. The main course, 1 ft. thick, was continuous over the entire area. It extended beyond the back of the retaining walls a short distance, so as to give a good footing for them, and was put in, generally, about 1 ft. thicker under these walls, as an additional foundation for them. An additional foot and sometimes more was placed under the points where the pillars for supporting the roof were originally intended to be set, the additional thickness

at each point covering an area 6.6 ft. square. This formed a large volume of concrete, in all about 5 500 cu. yds., to be spread in so thin a sheet over so large an area. Great care was necessary in preparing the ground for its reception. The specified thickness was obligatory, and, on the other hand, no extra thickness would be paid for. The ground had therefore to be dressed to as nearly a perfect level as possible at the exact elevation of the bottom of the concrete.

The stone mostly used for this concrete was in every respect admirably adapted for the purpose, being an exceedingly hard crystalline limestone, breaking readily in the crusher with a sharp conchoidal fracture. The sand used for all the work was calcareous, there being no siliceous sand procurable. It was sharp, very clean, and gave excellent results. The bulk of the cement used on the work was an English Portland, extra fine grinding, which gave perfect satisfaction. When shipments were delayed, foreign Portland of various brands was bought of the Havana dealers at naturally higher figures. Toward the end of the work, a considerable amount of American Portland was used, with good results. The reciprocity treaty coming into effect at that time made it very desirable to use American materials, as far as possible, for economic reasons.

The keeping of the concrete thoroughly wet for long periods of time after being placed was inflexibly insisted upon. This precaution was doubly necessary in such a climate as that of Cuba, and was enforced for all classes of masonry. There was an abundant supply of water, and the work of wetting everything down was carried on by hose, and by boys with large watering pots. Brooms were also in constant requisition to keep all work thoroughly clean, so as to ensure a good bond of the mortar.

The greater part of the concrete was prepared by the mixer. The proportions used were one part of cement, three parts of sand, and six of broken stone. The ingredients were measured out on the platform of the machine, and the cement and sand mixed dry, by hand. The stones were then wet, and each batch shoveled into the hopper in such a way as to secure a homogeneous mixture. The water was added gradually by a man stationed where he could see the finished product as it was fed out into the car, so as to keep it of the right consistency. The concrete was sent down in cars by an inclined plane. As the time for the rainy season approached, it was feared that the concrete floor would

not be finished before the rains set in, and that consequently much of the unfinished work would be lost. The machine was therefore supplemented by several gangs mixing hand-made concrete, which was neither as good nor as economical as the machine-made product.

As a proof of the good quality of the concrete, it may be mentioned that a large block, 2 or 3 ft. thick, was placed to form the bottom of a receiving basin adjacent to one of the overflows. This basin was built upon a fill, and, although every care was taken to consolidate the earth filling, it began to show signs of settlement. It became necessary to remove the basin and excavate to the natural ground for a new foundation. The concrete was less than three months old when it was removed, and in that time had become so hard that powder was needed to get it out. It came out in large blocks, some fully half a cubic yard in size, and these blocks were dogged and lifted out by the derrick, and afterwards used as blocks of stone in the new foundations.

In executing the masonry work great difficulty was experienced in getting sufficiently large stones for rapid work in the rubble masonry. The quarries were badly worked by the parties furnishing the material, who were without proper appliances for the purpose. All the stone used in the rubble and cut-stone work might probably be classed as coral limestone and limestone conglomerate, a good quarry of this latter being found in the immediate vicinity of the work. The material for cut stone could be obtained in almost any size desired. It was a peculiar class of the above-mentioned coralline, very soft and easily cut by stone axes into any required shape. It was quarried by chopping channels with axes, and then wedging the blocks out. It was easily worked, but was naturally an inferior material as regards durability.

The inside faces of the reservoir walls were plastered with one part cement, one part sand and one part lime. The author objected to the use of lime, but as this was a mixture ordered by the director, it was, of course, put in. It stood well, however, and, so far as the author knows, is still standing. The floor of the reservoir was finished with a plastering of one part of cement and two of sand.

After the first bed of concrete, 1 ft. thick, was placed, concrete blocks about 5 x 5 x 1.3 ft. were set for the bases of the granite pillar blocks, in case they should be wanted. These blocks were brought up to their

exact elevation, and when the last layer of concrete was applied, which was laid with a sloping surface, the proper height for the finished surface was marked upon each block, and served to keep a true grade for the floor.

Work when fairly commenced was vigorously prosecuted. The great drawback was the impossibility of getting the excavation out fast enough for the concrete and masonry, Although the bulk of the excavation had been taken out the previous season, there still remained a great deal to do to get out and down to the outside lines of the work, especially as the bank, which was generally about 20 ft. high, occasionally caved in. The material had frequently to be handled over more than once, because it was necessary to get out the foundations faster than the earth could be removed from the site. The great reliance in hoisting out the earth was the inclined plane operated by the stationary engine, but scales and derricks were also used. The loaded dump cars were also swung out of the pit bodily by a strongly guyed derrick, landing them on a track on the bank, whence an ox team would take them off to the dump and return them to the derrick. It would have been good judgment to have had two engine planes for the removal of the material, but this fact was not realized until it was too late to send to the United States for the necessary plant.

The rain caused great delays. The author had been led to believe, both by common report and his own experience on previous visits, that the winter months would be quite free from rainfall, and so, in general, it is believed they are, but during this and the succeeding year copious rains fell at intervals through the winter months, and between the legitimate rainy seasons. On the other hand, in June, 1891, dry weather occurred where rain had been anticipated and provided for by putting on extra gangs, at a heavy expense, to complete the concreting of the floor before June 1st. As it proved, this extra expense might have been spared, but this was only by a chance, which could not have been counted on.

The original drawings showed a uniform section of retaining wall for all four sides of the reservoir. It was evident, however, from the nature of the ground that the pressure would be greatest upon the south side. Accordingly, some counterforts were built into the back of the wall, as a palliative measure for its lack of stronger section. In spite of this precaution, a portion of the unfinished south wall ad-

vanced bodily into the reservoir, forming the arc of a circle, with a versed sine of not quite 6 ins., the wall otherwise showing no apparent change of form. The earth was immediately removed in part from behind it to relieve the pressure, and no further movement took place, a few slight cracks only being visible on the face. This circumstance, under the peculiar laws regarding responsibility, threatened to become an embarrassing one, but the matter was finally decided by the authorities in a spirit of fairness. Enough of the injured wall was taken down to remove the cracked portions, and to enable the top to be rebuilt on a straight line. Advantage was taken also of the opportunity to increase the dimensions of this part of the wall so as to insure against a repetition of the disaster. In removing the damaged portions it was necessary to use light charges of powder. In fact, this mishap rendered very conspicuous the excellence of the materials and work put into the wall.

Late in August, 1891, the work was suspended for the season, the concrete flooring being completed, with the exception of the finishing course, and the retaining walls on all sides finished with the exception of a gap left for drainage and some intervals left for subsequent construction.

Work was resumed early in November of the same year, and carried on vigorously, although there was a great deal of rain both in this and the following month. It was now determined to dispense with all help brought from the United States, and from the suspension of the work in August to its completion only local help was employed, with the exception of a few Italian-American masons, who had drifted dov n on their own responsibility.

In February of 1892 the author's principal assistant, Mr. Victoriano García San Miguel, a Spanish officer of engineers, returned to Spain, and his place was taken by Ernesto J. Balbin, M. Am. Soc. C. E., who had previously been assistant to the director, Major Ruiz.

After the resumption of the work the center wall was built, as well as the influent and effluent gate chambers. This last was an extensive and imposing structure. It comprised much cut-stone work. Fig. 2, Plate VII, is a view of the work looking southwest, which was taken May 13th, 1892. It shows the work of concreting of the bottom with both hand and machine-made concrete, and the beginning of the construction of the effluent gate chamber.

Early in November, 1892, rather less than two years from laying the first stone, the work was practically completed, with the exception of some exterior work, and both tanks were filled with water, experimentally. Everything proved to be all right. In January, 1893, the principal part of the piping of the city having been completed, the reservoir and pipes were filled, preparatory to the official inauguration of the works. This took place January 23d, under the auspices of the Captain General and Bishop of Havana. Fig. 1, Plate VIII, is a view looking north down the center wall, when both tanks were full. It was taken January 21st, 1893, two days before the inauguration. Fig. 2, Plate VIII, is a view of the completed work, except grading and iron gates in openings in the wall surrounding the reservoir.

The final estimate for the Palatino Reservoir is as follows, the quantities being reduced to English measures and the prices paid to American currency:

| | | | | |
|---|---|---|---|---|
| Excavation | 89 474 | cu. yds. at | $0 70 | $62 631 80 |
| Embankment | 126 983 | " " | 0 49 | 62 221 67 |
| Terracing | 30 796 | " " | 0 42 | 12 934 32 |
| Concrete | 8 860 | " " | 15 22 | 134 849 20 |
| Rubble, 1st class | 10 576 | " " | 12 78 | 135 161 28 |
| " 2d " | 272 | " " | 10 88 | 2 959 36 |
| " 3d " | 946 | " " | 7 57 | 7 161 22 |
| " arches | 96 | " " | 13 00 | 1 248 00 |
| Cut stone, cornices | 57.31 | " " | 38 94 | 2 231 65 |
| " bridge stones | 69.47 | " " | 37 84 | 2 628 74 |
| " patterns | 1 186.66 | " " | 33 72 | 40 014 18 |
| " plain | 597.50 | " " | 29 52 | 17 638 20 |
| " 2 beds | 410.00 | " " | 25 23 | 10 344 30 |
| Brick | 741.00 | " " | 17 09 | 12 663 69 |
| Dry stone | 296.00 | " " | 5 26 | 1 556 96 |
| Plastering, 1st class | 5 448 | sq. yds. at | 1 51 | 8 226 48 |
| " 2d " | 19 540 | " " | 0 92 | 17 976 80 |
| Paving, concrete | 1 424 | " " | 2 29 | 3 260 96 |
| " brick | 690 | " " | 1 15 | 793 50 |
| Face work on cornices | 106 | " " | 2 75 | 291 50 |
| Graveling terrace | 500 | " " | 0 69 | 345 00 |
| Tile drains, 1 305 running feet | | " | 0 67 | 874 35 |
| Timber grillage, 10 100 ft. B. M | | " | 28 60 | 288 86 |
| Gates, valves, etc | | | | 13 832 41 |
| Iron work, stairs, railings, etc | | | | 12 434 81 |
| Miscellaneous | | | | 1 917 27 |
| Total | | | | $566 486 51 |

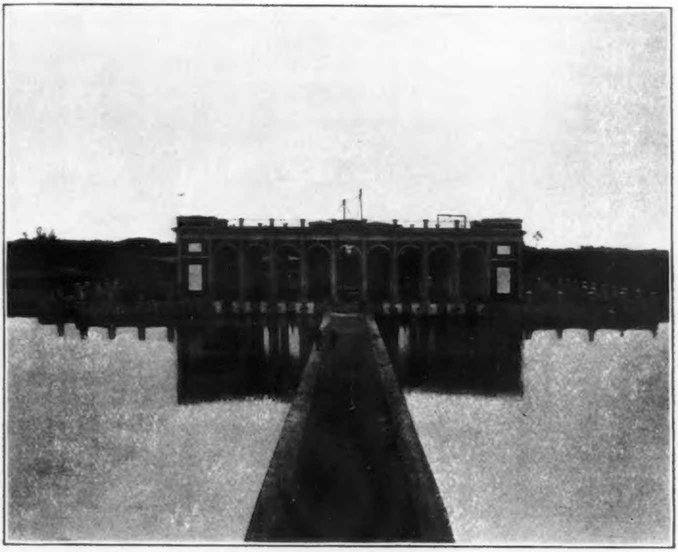

FIG. 1.

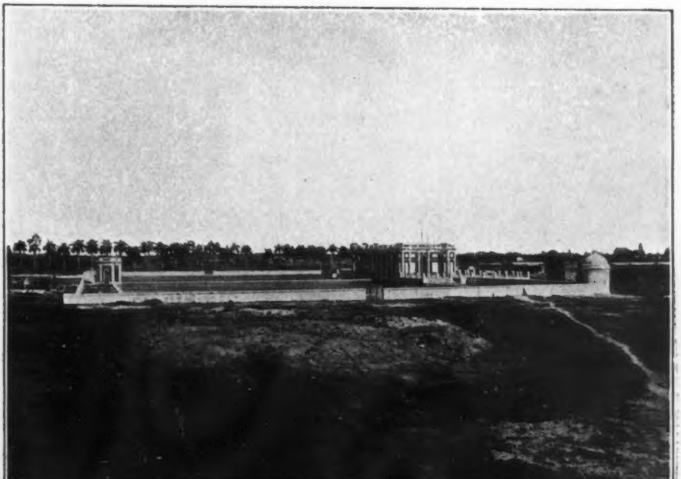

FIG. 2

The quantities and prices, in English measures and United States currency, of the pipe system, according to the final estimate, were as follows:

| | |
|---|---|
| Cast-iron straight pipe, 7 930 tons at $85 39..... | $677 142 70 |
| Lead, 320 682 lbs. at 6 cents.................... | 19 240 92 |
| Hauling, 7 930 tons at $2 50.................... | 19 825 00 |
| Pipe laying, 465 655 lin. ft. at $1.022 (average price) .................................. | 475 899 41 |
| Gates, valves, hydrants and various specials, 88.19 miles at $1 272........................ | 112 177 68 |
| House connections and services, 88.19 miles at $760 10.................................. | 67 033 22 |
| Masonry, earthwork, pile-driving, etc., on 42-in. pipe line, 2.51 miles at $60 025 50........... | 150 664 00 |
| Unclassified ................................. | 44 391 65 |
| Total.............................. | $1 566 374 58 |

The manner of making up the engineer's estimate for this class of public works, according to Spanish rule, is to calculate as nearly as possible the actual cost at which it can be done, and then add 19% for contractor's profit. In the above statement, the 19% is added in for each item separately, as giving a clearer idea of the actual prices paid.

The length and weight of pipe, and the weight of the lead used for the different diameters, were as follows:

| Diameters. Inches. | Length. Feet. | Weight. Tons (2 240 lbs.). | Lead. Pounds. |
|---|---|---|---|
| 42.................................. | 13 236 | 2 380 | 88 950 |
| 20.................................. | 21 650 | 1 273 | 61 812 |
| 12.................................. | 26 858 | 797 | 47 751 |
| 8.................................. | 34 712 | 590 | 3 042 |
| 4.................................. | 338 431 | 2 715 | 113 566 |
| 3.................................. | 30 768 | 175 | 5 561 |
| Totals.................... | 465 655 | 7 930 | 320 682 |

The construction of the Palatino Reservoir was under the author's exclusive charge, and he held, also, the position of consulting engineer for the entire enterprise covered by the contract of Messrs. Runkle,

Smith & Co. The pipe laying was under the immediate charge of Mr. Simonetti.

Four pipes ran out from the collecting pipe in the effluent gate chamber. One 12-in. pipe was for the supply of the Cerro district, adjacent to the reservoir; one 20-in. for that of the Jesus del Monte district, also near by; another of 20 ins. diameter, to be connected, if necessary, with the old or Fernando Sétimo system, and the main 42-in. pipe for the general supply of the city. This last pipe extended about 2½ miles, crossing two valleys on masonry arcades, not included in the estimate for the reservoir, to an elevated point in the city, whence branches were run through the various streets.

The service pipes of wrought iron rapidly corroded in the impure soil in which they were laid, and were the cause of much trouble and expense for renewals.

The author desires to acknowledge his indebtedness to the gentlemen already named as connected with him in the work for the faithful, zealous and efficient co-operation which they rendered him in carrying out the undertaking. He is also indebted to Mr. Pelaez for the historical data given in the beginning of this paper.

Besides those whose names have been already mentioned, J. A. Ruiloba, Jun. Am. Soc. C. E., Mr. Fortun, a Cuban engineer, and Mr. Domingo Del Monte, were at different times employed on the work, and all did well in their several capacities.

The benefits accruing to the city of Havana by the execution of this work have been enormous. An abundant supply of exceptionally pure water has been introduced into all parts of the city, including those districts which previously were unprovided with any water except what was brought in pails from public plugs. It is true that, as the draught upon the supply increases, the pressure diminishes, and inconvenience has been already experienced from this cause. This inconvenience was apprehended and pointed out by the author when the work was commenced, and a diameter of 48 ins. recommended for the 13 236 ft. of main running out of the reservoir, instead of the 40 ins. originally contemplated. The extra cost was regarded, however, as prohibitive, and a diameter of 42 ins. was finally settled upon. The 48-in. main would in this distance have given over 15 ft. additional head at the point where the smaller mains branched off. That is, the calculated piezometric head at this point being at

elevation 83.6 ft. with a 42-in. main, would have been at 99 ft. with one of 48 ins., a gain of about 18%, which, under the circumstances, would have been of immense benefit.

As a growing interest is taken in work in Spanish American countries, some general reference to this class of enterprise may be looked for in this paper. The experience and observation of the author in Cuba and elsewhere lead him to the following conclusions:

*First.*—The hope of reaping extravagant profits from such undertakings must not be entertained. No matter how favorable the contract or concession may be, a host of unforeseen difficulties are sure to arise owing to many causes, the partial enumeration of which, even, cannot be entered into here.

*Second.*—The work must be carried on with precisely the same economy, energy and attention to detail which would be considered essential to success at home.

*Third.*—As far as possible local help and materials should be employed, and methods of work made to conform to local usage.

*Fourth.*—No such enterprise should be undertaken unless sufficient capital has been secured to start and carry on the work rapidly and vigorously. The author is convinced that the striking success which, in spite of all obstacles, crowned the work just described, was very largely due to the sound and liberal basis upon which the undertaking was financed by its promoters.

# DISCUSSION.

Mr. Clarke. THOMAS CURTIS CLARKE, M. Am. Soc. C. E.—An interesting method of dealing with soft foundations has been followed by the engineers of the Canadian Pacific Railway in crossing muskegs or tamarack swamps. Gravel was formerly used, and an enormous quantity was required, as it would sink deep and spread out. Sawdust is now employed. About half the number of cubic yards, as compared with gravel, is needed to make a perfectly solid and reliable bank. This is covered with about 2 ft. of gravel and stands much better than the older work.

Mr. Wegmann. EDWARD WEGMANN, M. Am. Soc. C. E.—The sliding of the reservoir wall mentioned in the paper recalled to the speaker the movement of the abutments of a bridge on the New York, West Shore and Buffalo Railroad, about a mile north of Haverstraw, N. Y. At the place in question, an embankment 45 ft. high had to be made across a swamp to Cedar Pond Creek, which was to be crossed by a bridge of about 64-ft. span. As the swamp was very soft and about 20 ft. deep to hard bottom, it was decided to support the embankment by corduroy made of two courses of 6-in. saplings. This expedient was, however, of little value, as the weight of the embankment broke the corduroy and forced it to either side. The abutments of the bridge, which were about 45 ft. high, were constructed on solid pile foundations. During a freshet the creek, which had originally a depth of only 3 ft., scoured out its channel between the abutments so as to be 8 to 12 ft. deep at this place. Although the foot of the embankment approaching the south abutment was, at the time, at a distance of nearly 200 ft., the pressure in the swamp due to the weight of the embankment caused this abutment to move bodily about 1½ ft. towards the creek, without a crack being produced in the masonry. This movement was, of course, facilitated by the deepening of the creek.

The north abutment, except its wing walls, which were built on hard bottom, was also forced towards the creek by the north embankment, so that the span was reduced by about 2½ ft.

To stop the sliding, piles about 62 ft. long were bolted together in pairs, tip to butt, and placed as horizontal braces between the abutments, as a temporary expedient. In order to prevent any further scouring of the creek channel, sheet piles were driven across the creek just above and below the bridge. A crib-pier, reaching from one set of sheet piles to the other, was sunk half way between the abutments, stones being filled around the crib and between the sheet piling to bring the creek bottom to its original level. An invert of 12 x 12-in. timbers was then constructed so as to brace one abutment against the

other, each of the timbers resting at one end on the crib pier and at the other against one of the abutments. This arrangement stopped all further movement, and has ever since held the masonry in place. Mr. Wegmann.

E. J. Chibas, Assoc. M. Am. Soc. C. E.—Some of the results of the Spanish method of awarding contracts in Cuba, referred to in the paper, are interesting. If the owner of a Cuban plantation desires to build a railway to some point on the sea coast or elsewhere, he has to file an application, before any work is done, with the Department of Public Works of the Province, even though the proposed work will be entirely on his own property. This application generally lies there from one to two years, according to the influence the planter can bring to bear on the Spanish officials. After it leaves the provincial office it goes to Havana, and finally to Madrid. After waiting from four to six years the petition may be granted, each stage in its progress requiring influence of one sort or another to push it along. The application then comes back to the island and the railway may be begun. In one case a small horse tramway was needed by a planter who was versed in the ways of the officials. He accordingly applied for a permit to build a regular railway; after some discussion a compromise was effected and he received his tramway permit, and saved a considerable part of the expense to which he would have been put had the original application been made out for the real object in view. It is on account of these laws, which make it necessary to spend several years and considerable money to secure permits, that many needed improvements have not been made in Cuba. The customs in the Spanish-American republics are not the same as in Cuba, and follow more the general practice in the United States. Mr. Chibas.

## CORRESPONDENCE.

Mr. Christian. G. L. CHRISTIAN, Assoc. M. Am. Soc. C. E.—The author has not mentioned some features of this work which it would be interesting to learn about, such as whether the excavation was in clay or sand, and whether the gates were closed for a definite time when the reservoir was first filled, and the subsidence, if any, noted, and the proportion due to evaporation estimated. It would seem as though a reservoir so well built and on which everything was done on such a liberal basis could not leak much, and the author has just cause for feeling proud of the strength displayed by the concrete, when only three months old.

It will be noticed that foreign Portland cement was used almost exclusively in the work mentioned, which reminds the writer of the time it was found necessary to remove a small part of the brick masonry in a reservoir gate-house to make a slight change from the original plans. The work had been done less than a year, and it was found impossible to separate the bricks, the whole being one homogeneous mass. The cement used in this work was an American Portland mixed in the proportion of two parts of sand to one of cement.

Mr. Low. EMILE LOW, M. Am. Soc. C. E.—It is stated in the paper that the Palatino Reservoir is almost wholly in excavation. The cubature of the extreme dimensions is about 90 000 cu. yds., while the amount of excavation in the final estimate is 89 474 cu. yds. There are also two more items of earthwork, 126 983 cu. yds. of embankment and 30 796 cu. yds. of terracing, concerning which more information is desirable. A considerable saving might apparently have been effected by reducing the depth of the cutting and utilizing the excavated material for an embankment back of the masonry wall. With a fixed width of embankment and a definite slope, the amounts of excavation and embankment could have been made to balance to a nicety. The nature of the soil or the position of the inlet and outlet pipes may have determined the location of the reservoir, but the paper fails to disclose the reason for the plan adopted.

The author deprecates the fact that large stone for rubble masonry was obtained with difficulty. Although this may have been detrimental to the contractor's pecuniary interests, it would seem that stone of medium size, bearing some ratio to the thickness of the wall, would be likely to make more water-tight work, on account of a greater possibility of breaking joints and the prevention of joints reaching through the wall from face to face. In this connection, attention is called to an accident which occurred at a masonry reservoir at Saltville, Va., used to store crude and clarified brine.

The reservoir measures 195 x 165 ft. along the outside top edge of the walls. It is divided into four basins, two of which measure 120 x 75 x 7 ft., and two 72 x 57 x 12 ft. At the side of the reservoir there was a top layer of alluvial soil from 2 to 3 ft. thick, then a layer of clay of about the same thickness, and below this a bed of gravel from 4 to 6 ft. thick, resting on soft, friable limestone. The bottom was a bed of concrete about 1 ft. in thickness, made of an American Portland cement, sand and gravel mixed by hand. As soon as this bed became hard enough, the brickwork of the walls was started. It was proposed originally to lay the brick in cement mortar, but lime mortar was used, for economical reasons. The work was done by laying the concrete below the walls in trenches, starting the brickwork as soon as possible, and then excavating the earth in the basins and putting in the remainder of the concrete bottoms. These last were formed in sections by placing mold boards on the finished earth surface, parallel to the side walls at about 10-ft. intervals, and also along the diagonals of the bottom. As the work was done during a season when the temperature frequently dropped below the freezing point in the nights, fires were kept all night as near the fresh concrete as possible. Work was carried on during the winter whenever the weather was mild, and by spring the last bricks were laid. Mr. Low.

With the advent of warmer weather, the inside walls were plastered with cement mortar. But little trouble was experienced with this plaster except on two sides of one of the deep basins, where surface and ground water was percolating through the wall. Portions of the surface of the concrete were badly disintegrated, and cracks were found following the lines of juncture of the sections in which the concrete was laid. It was then decided to plaster the bottom with cement mortar. Water was coming up through minute openings at irregular intervals in the concrete of the basin with leaking walls, and, after various expedients to get rid of it, short pieces of small wrought-iron pipe were driven into the openings, through which the water was allowed to issue. As it became warmer the plaster coat cracked and scaled off from the concrete, especially in the compartment giving the most trouble.

It was necessary to put the reservoir in service, but, after the basins were filled, brine was found to be percolating through the division walls, particularly those between the deep and shallow compartments. Tests showed that considerable fresh water was entering one of the deep compartments, reducing the strength of the brine and making it unavailable for the uses intended. The basin was pumped out, and water found to be issuing freely through the iron pipes. Large flakes of the plaster side lining were detached, and part of that on the bottom was also loose. These were removed and all defective surfaces replastered. Excavations were made for puddling the outside of the

Mr. Low. walls of this particular division, when an accident occurred, threatening the safety of the entire reservoir.

About 40 ft. of the division wall (Fig. 1), between two of the basins, fell into the deeper compartment. At the time there was 5 ft. 10 ins. of brine in the shallow basin, and 6 ft. 6 ins. in the other, the difference between the respective water levels being 4 ft. 4 ins. The brine in the basins was drawn off as rapidly as possible, and it was found that the entire wall above the level of the shallow basin had been swept off, and the bricks thrown in a fan-shape mass nearly across the deep basin. The mortar was soft and did not adhere at all to the bricks. Several of the face courses of the lower portion of the wall were removed and replaced by bricks laid in cement and lime mortar. The upper part

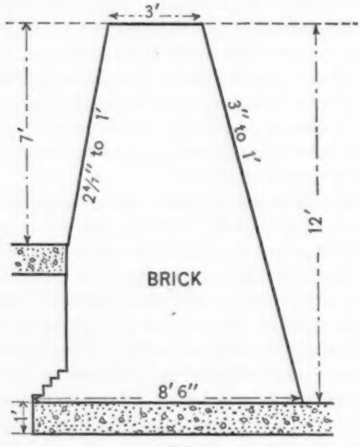


FIG. 1.

of the wall was relaid with the same mortar, using the old bricks as much as possible after cleaning them by a stream from a hose, which washed off the mortar.

The square corners at the connecting ends were rounded off, and the bricks on the faces of the lower parts of the walls of both deep basins were removed to a depth of 12 ins. and replaced by new bricks laid in cement mortar. Heavy counterforts, four in all, were built at the centers of the high walls and projected well into the basins. All loose plastering was replaced by fresh, and a prism of cement mortar placed along the bottom inside edges of all walls.

Mr. Le Conte. L. J. LE CONTE, M. Am. Soc. C. E.—Inasmuch as the practice of covering service reservoirs, located in tropical countries, is now gen-

erally regarded to be the proper thing, it would be of interest to know what grounds, other than economy, the city officials had for objecting to the construction of a covered reservoir. **Mr. Le Conte.**

The author's remarks in regard to the relative value of machine and hand-mixed concrete naturally invite discussion. The class of mixer used, the proportioning being first done by hand, gives the best results, no doubt. Those who have had much experience with both kinds of mixings generally agree that the chief advantage obtained in machine-mixing is that of economy and not of excellence. The cost of labor is greatly reduced and the daily output is very much increased. These are great practical advantages which will always be the controlling factors in deciding the system to be adopted in most cases in every-day practice. On the contrary, wherever the concrete called for is of high grade and is to be subjected to heavy or violent shocks, the fact remains that hand-mixed concrete is always preferable, for the generally admitted reason that it is a more reliable mixture.

Among the weak points about machine mixing may be mentioned the fact that the plant is so cumbersome and inconvenient to move from place to place that it is rarely placed close to any particular piece of work, but at some distance, so as to be more central and more generally useful to the work as a whole. This necessitates transportation from the mixer to the tamping work, and here is where the trouble occurs. The writer has noted a large number of cases in which the freshly mixed concrete, after being transported, say 200 to 300 ft., and dumped at the site of a bridge pier, was found to be invariably more or less separated or unmixed, so much so that the final mixing was in point of fact actually done by the tampers in the bed-work. In case of hand-mixing, operations can always be held within circumscribed limits and thus the trouble about separation due to transportation may be largely avoided.

It is to be regretted that the author did not give more details as to original designs and modifications brought about by unexpected contingencies. Accidents will happen, and the facts and discussions which they bring out from experienced members are always interesting and instructive.

E. Sherman Gould, M. Am. Soc. C. E.—Mr. Clarke's remarks about the use of sawdust in railroad embankments are interesting and valuable, as are also Mr. Wegmann's on the method of shoring up bridge abutments, under certain peculiar circumstances. Mr. Chibas' observations on the peculiarities of official methods in the Island of Cuba are interesting supplements to those in the original paper. It may be further remarked that not only are the different classes of work kept distinct, as stated, but the work itself is divided up into parcels which are kept independent of each other. Thus, in the work described, there was a separate estimate for the reservoirs, the influ- **Mr. Gould.**

Mr. Gould. ent and effluent gate chambers, the discharge culvert, etc., and there could be no giving and taking of quantities between these items, so that a shortage in one could not be made good from a surplus in another. Needless to say, that these cast-iron regulations necessitate the exercise of considerable ingenuity in making up the final estimate or *liquidacion*.

In answer to Mr. Christian, the material excavated was chiefly stiff clay. The completed work was turned over to the city, and it is believed that no such experiments as those suggested were made by the authorities.

In reply to Mr. Low, the reservoir was chiefly, though not wholly, in excavation, as the surface of the ground was somewhat irregular. The elevation of the bottom of the reservoir was fixed by that of the collecting basin at Vento, and the location was selected as being, upon the whole, the most favorable. A great deal of filling in, leveling, grading, etc., was done which is included in the item of embankment.

The facts, frankly given, regarding the collapse of some brine tanks, are instructive, as those relating to failures always are.

In answer to Mr. Le Conte's inquiry as to the motives of the city officials for their attitude in regard to the covering of the reservoir, the author can only reply, *Quien sabe?*

As to the relative merits of machine and hand-made concrete, the author would say that his preference is decidedly for the machine-made product, when the machine is properly operated. The labor of turning over a bed of concrete by hand, so as to thoroughly incorporate the ingredients is so great that it is apt to be slighted, and it is doubtful if the mixture is ever so complete as when the mass is churned up mechanically by steam power. In the present case, the product was fed directly into the wagons, which were then run down to where the concrete was to be used, and dumped bodily, either in place or in close proximity to it. It may be remarked that the Decauville, or other sheet-iron or steel, wagons are the best for this purpose.

Much might have been added to the paper in the way of details of the work, modifications of the original plans, etc., but the author's purpose was rather to give a brief and general statement of the leading features of an important foreign work undertaken and successfully completed by American capitalists.